INFLUENCE OF PRESTORAGE CARBON DIOXIDE TREATMENTS ON THE QUALITY OF 'd'ANJOU' AND 'BARTLETT' PEARS

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ABSTRACT

'd'Anjou' and 'Bartlett' pears (Pyrus communis *L.) were treated with 12% CO_2 for 14 days at -1C and then stored in either regular (RA) or controlled-atmosphere (CA) storage for various periods of time. After each storage period, pears were evaluated for quality attributes. Compared to nontreated fruit, CO_2-treated 'd'Anjou' pears from RA storage were firmer, greener, and displayed reduced rot, scald and internal breakdown and better pedicel condition. High CO_2 treatment of 'Bartlett' pears prior to RA storage resulted in reduced quality after storage. Prestorage CO_2 treatment of 'Bartlett' pears reduced poststorage firmness and TA and increased incidence of scald, but reduced surface damage during ripening. High CO_2 treatment prior to 120 or 220 days of CA storage had no effect on the poststorage quality of either 'd'Anjou' or 'Bartlett' fruit.*

INTRODUCTION

In Washington the standard storage program for short-term (< 3 months) storage of pears (*Pyrus communis* L.) consists of regular atmosphere (RA) storage at -1C. For long-term storage of pears (up to 9+ months), a controlled-atmosphere (CA) storage environment (1.5% to 2% O_2 and <1% CO_2) at -1C is normally used (Hansen and Mellenthin 1979; Meheriuk 1993). The CA storage law in Washington State requires that winter pears be held in an atmosphere containing 5% or less O_2 for a minimum of 60 days before the fruit can be certified as CA stored (Washington Agriculture Code 16-449-010). No

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requirement for CO_2 level in the storage atmosphere is considered in the Washington Code.

High CO_2 treatment following harvest and prior to storage has been used successfully to extend storage life in both apples and pears. Couey and Olsen (1975) reported greater firmness and acid retention in apples treated with CO_2 for short periods before storage. Stow (1988, 1990) determined that treating apples with CO_2 immediately after harvest reduced loss of firmness and enhanced sensory quality but increased the risk of breakdown in storage. Lange (1988) found that high CO_2 treatment caused peel injury and only slightly reduced firmness loss in apples.

Treating pears with high CO_2 for short periods prior to storage can prolong storage life (Wang and Mellenthin 1975; Ke *et al.* 1990). 'Bartlett' pears exposed to short periods of high CO_2 had reduced respiration and ethylene rates coupled with enhanced firmness (Chavez-Franco and Cadre 1993; Kerbel *et al.* 1988). Merodio and Plaza (1989) found that ethylene production was suppressed in 'Blanc de Aranjuez' pears exposed to high CO_2 prior to storage. This research was conducted to determine the advantages or disadvantages of high CO_2 treatment for 'd'Anjou' and 'Bartlett' pears under WA conditions prior to both short-term (RA) and long-term (CA) storage.

MATERIALS AND METHODS

At harvest, two commercial pear storage warehouses provided a total of 54 packed boxes (18 boxes from each of 3 growers) of storage quality 'd'Anjou' pears and a total of 24 boxes (8 boxes from each of 3 growers) of storage quality 'Bartlett' pears. One day after packing, the pears were collected and transported to the commercial storage research facility located at Stemilt Growers, Wenatchee, WA. Thirty-six boxes of 'd'Anjou' and 12 boxes of 'Bartlett' pears were exposed to 12% CO_2 at -1C, for 14 days. Pears used as controls were held at the same temperature, but not treated with CO_2. Prior to CO_2 exposure, box lids were removed and the liners opened to assure uniform exposure. After exposure of the pears to CO_2, the liners were closed and the box lids replaced. Treated and nontreated boxes of 'd'Anjou' and 'Bartlett' pears were stored together in either RA at -1C or CA (1.5% O_2 and 1% CO_2) at -1C. The CA atmosphere was established and maintained using a purge-type computer-controlled CA system (Technical Consulting Services, Chelan, WA). A Servomix gas analyzer (Model 1400B4, Norwood, MA) was used daily to determine CA atmosphere concentration. After 90, 120, 150 and 180 days ('d'Anjou') and 90 days ('Bartlett') in RA, one box of each pear cultivar and from each grower was removed for quality evaluation before and after ripening. After 90, 150 and 220 days ('d'Anjou') and 120 days ('Bartlett') in CA, two

boxes of 'd'Anjou' and one box of 'Bartlett' pears from each grower were removed from CA storage for quality evaluation. Fruit quality parameters were evaluated on 20 pears immediately after removal from storage and on 20 pears after an additional 3 ('Bartlett') or 7 ('d'Anjou') days at 20C. The remaining pears in a box were used to evaluate the incidence of poststorage rot. The remaining boxes of 'd'Anjou' pears from CA storage (one from each grower and treatment) were held in regular atmosphere (RA) storage (1C) for an additional 30 days to simulate shipping and handling time and were evaluated after that time as described above. Quality factors evaluated were flesh firmness, external (skin) and internal (flesh) color, soluble solids concentration (SSC), titratable acidity (TA), finish (general appearance) and disorders (scald, pedicel condition, internal breakdown, and surface cracking).

Flesh firmness was determined using the TA-XT2 Texture Analyzer (Texture Technologies, Scarsdale, NY) equipped with a 7.7 mm probe. External and internal color were determined with The Color Machine (Pacific Scientific, Silver Springs, MD) using the Hunter L*, a*, b* system and hue angle values calculated from the measured a* and b* values (Hunter and Harold 1987). SSC and TA were determined from a composite sample of juice expressed from longitudinal slices from each of 20 fruit.

An Abbé type refractometer with a sucrose scale calibrated at 20C was used to determine SSC. TA was measured with a Radiometer titrator, model TTT85 (Radiometer, Copenhagen, Denmark). Acids were titrated to pH 8.2 with 0.1N NaOH and expressed as percent malic acid. Visible disorders (scald, internal breakdown, damage, finish and pedicel condition) in laboratory samples of fruit were determined by 2 individuals familiar with winter pear disorders. Scald, internal breakdown and damage (surface cracks) were rated as the presence or absence of visible disorders. Finish and pedicel condition were rated on a scale of 1 to 3 (1 = good, 2 = fair, 3 = poor; 1 = green, 2 = mottled, 3 = black). Data were analyzed using MSTAT-C (1988) in a completely randomized design with a factorial treatment arrangement using CO_2 exposure as the main plot and storage time and as the subplot. Means were separated following significant F tests using Tukey's HSD test.

RESULTS AND DISCUSSION

CO_2 treatment prior to storage resulted in better poststorage quality of 'd'Anjou' pears following 90 days of RA storage (Table 1). Firmness values were higher immediately after storage in pears treated with CO_2 compared to nontreated fruit. After 7 days of ripening, differences in firmness disappeared. Greater firmness in treated pears prior to ripening would help reduce scuffing and enhance appeal to consumers. Reduced scuffing during packing and shipping would be beneficial to both the packer and the retail outlet.

TABLE 1.
EFFECTS OF PRESTORAGE CARBON DIOXIDE TREATMENT (12% FOR 14 DAYS) AND RIPENING TIME (0 AND 7 DAYS) ON QUALITY ATTRIBUTES OF 'd'ANJOU' PEARS AFTER 90 DAYS OF REGULAR ATMOSPHERE STORAGE

			Peel Color		Subjective Evaluations			
CO_2	Ripe (days)	Firmness (N)	L*	Hue	Rot (%)	Scald (%)	Internal Breakdown[z] (%)	Pedicel Condition[y]
No	0	40.0b[x]	60.9c	97.2b	<1.0b	<1.0b	2.0b	1.5c
	7	9.4c	64.5a	89.6d	10.0a	1.0b	6.0a	2.7a
Yes	0	49.7a	58.3d	100.5a	<1.0b	<1.0b	<1.0b	1.3c
	7	9.9c	62.4b	93.2c	2.0b	2.0a	1.0b	2.0b

[z] Discoloration of the core area.
[y] Evaluated on a scale of 1 to 3 (1-green; 2-mottled; 3-black).
[x] Means in a column not followed by a common letter are significantly different by THSD test ($P \leq 0.05$).

'd'Anjou' pears treated with CO_2 were darker in peel color (lower L* values) and greener (higher hue values) than nontreated pears (Table 1). This difference in color between treated and nontreated pears was present both immediately after storage and after ripening. During 7 days of ripening the loss of green and increase in yellow advanced more rapidly in nontreated versus treated pears. Differences in peel color between treated and nontreated pears were in excess of 1 Hunter unit and would therefore be visible to the consumer (Hunter and Harold 1987). Internal color was not influenced by CO_2 treatment.

After ripening, nontreated 'd'Anjou' pears displayed 10% more rot than treated pears, would result in reduced consumer acceptance and increased loss at retail. A minor increase in scald incidence of 1% was observed in CO_2-treated pears after 7 days of ripening. It is doubtful that this difference in scald would be noticed by the consumer.

Pedicel condition (plumpness, greenness, absence of dehydration) is another way to assess pear fruit condition and quality. Pedicel condition was similar in treated and nontreated 'd'Anjou' pears immediately after storage (Table 1).

Pedicel condition deteriorated during ripening in both CO_2-treated and nontreated fruit, but the deterioration was much more rapid in nontreated pears. After 7 days of ripening, pedicel condition was rated as unacceptable (≤ 2) in untreated fruit but remained acceptable in CO_2-treated pears.

Duration of air storage influenced 'd'Anjou' pear quality (Table 2). Although CO_2 treatment did not affect flesh firmness after 90 days of storage, treated pears were firmer than nontreated pears after 120, 150 and 180 days of storage. The decline in firmness, of nontreated pears beyond 90 days of air storage was very rapid. Treated pears displayed no firmness loss until 180 days of storage, at which time they were similar in firmness to nontreated pears after 120 days of storage. Peel color change was also more rapid in nontreated pears than treated pears. Nontreated pears lost color (reduced hue values) between 90 and 180 days of storage. No change in hue values of treated pears was detected until 180 days of storage, at which time the hue values for treated pears were similar to hue values for nontreated pears after 120 days of storage.

Subjective quality evaluations (rot, internal breakdown, pedicel condition, and finish) were affected by CO_2 treatment during storage (Table 2). CO_2 treatment did not affect incidence of rot or internal breakdown until 180 days of air storage, at which time incidence of both rot and internal breakdown was greater in nontreated 'd'Anjou' pears. Pedicel condition deteriorated in nontreated pears during storage, reaching an unacceptable level (≤ 2) by 120 days in storage. Pedicel condition was rated as acceptable (≤ 2) for CO_2-treated pears during the entire 180-day storage. Fruit finish scores were rated as acceptable for treated and untreated fruit at 90, 120 and 150 days in storage. At 180 days of storage, finish scores for nontreated fruit exceeded an acceptable level (2 or $>$), while the finish scores for treated fruit remained acceptable (<2).

Exposure of 'Bartlett' pears to high CO_2 treatment prior to RA storage resulted in reduced fruit quality (Table 3). Nontreated fruit were firmer than treated fruit immediately after RA storage, but after 3 days of ripening, firmness was similar between treatments. Nontreated pears contained less titratable acidity than treated pears after storage, but after 3 days nontreated fruit were equivalent in titratable acidity. Scald increased dramatically during the 3-day poststorage ripening period, but pears treated with CO_2 displayed a higher incidence of scald (83%) than nontreated pears (48%). Treated pears were greener (higher hue values) than nontreated pears upon removal from storage, but after 3 days of ripening, skin color differences had disappeared. Internal flesh color of 'Bartlett' pears was not influenced by CO_2 treatment. Incidence of surface cracking (damage) was greater in treated pears immediately after storage. After 3 days of ripening, nontreated fruit showed much more surface cracking than treated fruit, which did not increase in cracking during ripening.

TABLE 2.
EFFECTS OF PRESTORAGE CARBON DIOXIDE TREATMENT (12% FOR 14 DAYS) AND TIME IN REGULAR STORAGE (90, 120, 150 AND 180 DAYS) ON QUALITY ATTRIBUTES OF 'd'ANJOU' PEARS

CO_2	Storage Time (days)	Firmness (N)	Peel Color (hue)	Subjective Evaluations			
				Rot (%)	Internal Breakdown[z] (%)	Pedicel Condition[y]	Finish[x]
No	90	32.3a[w]	97.9a	<1.0c	<1.0b	1.6cd	1.0c
	120	25.9b	93.4b	<1.0c	<1.0b	2.1b	1.3bc
	150	20.7c	93.0b	<1.0c	<1.0b	2.3b	1.1bc
	180	19.9c	89.2c	20.0a	15.0a	2.6a	2.3a
Yes	90	32.9a	98.2a	<1.0c	<1.0b	1.5cd	1.0c
	120	31.3a	97.2a	<1.0c	<1.0b	1.8c	1.2bc
	150	30.1a	97.7a	<1.0c	<1.0b	1.4d	1.3bc
	180	25.0b	94.3b	3.0b	2.0b	1.8c	1.5b

[z] Discoloration of the core area.
[y] Evaluated on a scale of 1 to 3 (1=green; 2=mottled; 3=black),
[x] Evaluated on a scale of(1=good; 2=fair; 3= poor).
[w] Means in a column not followed by a common letter are significantly different by THSD test ($P \leq 0.05$).

TABLE 3.
EFFECTS OF PRESTORAGE CARBON DIOXIDE TREATMENT (12% FOR 14 DAYS) AND RIPENING TIME (0 AND 3 DAYS) ON QUALITY ATTRIBUTES OF 'BARTLETT' PEARS AFTER 90 DAYS OF REGULAR ATMOSPHERE STORAGE

				Peel Color		Subjective Evaluations		
CO_2	Ripe (days)	Firmness (N)	Titratable Acidity (% malic)	L*	Hue	Rots (%)	Scald (%)	Damage (%)
No	0	56.2a[y]	0.20b	68.8a	81.4b	<1.0b	7.0c	0.0c
	3	29.2c	0.21b	69.9a	75.9c	12.0a	48.0b	34.0a
Yes	0	51.9b	0.23a	68.8a	85.0a	2.0ab	5.0c	18.0b
	3	30.4c	0.19b	69.5a	76.8c	10.0ab	83.0a	15.0b

[z] Damage was rated as the presence or absence of visible surface cracks.
[y] Means in a column not followed by a common letter are significantly different by THSD test ($P \leq 0.05$).

CO_2 treatment of either 'd'Anjou' or 'Bartlett' pears prior to CA storage had no influence on poststorage fruit quality. After 220 days in CA storage, CO_2-treated and nontreated 'd'Anjou' pears were similar in quality (data not shown). Holding 'd'Anjou' pears for an additional 30 in RA after CA storage, resulted in similar quality between treated and nontreated pears. After 120 days in CA storage, CO_2-treated and nontreated 'Bartlett' pears were similar in quality with the possible exception that firmness was slightly reduced in the CO_2-treated fruit (data not shown).

CONCLUSIONS

Prestorage CO_2 treatment of 'd'Anjou' pears maintained firmness and green color while diminishing the incidence of rot, scald, internal breakdown and deterioration of pedicel condition compared to nontreated pears under RA

storage conditions. In contrast, high CO_2 treatment of 'd'Anjou' pears destined for CA storage did not result in maintenance of better fruit quality following the storage period. Interestingly, a similar prestorage high CO_2 treatment of 'Bartlett' pears did not result in any benefit in poststorage fruit quality from either RA or CA storage.

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